Office of Life & Microgravity Sciences & Applications (OLMSA)

...and the Challenges of Human Space Flight

Arnauld E. Nicogossian

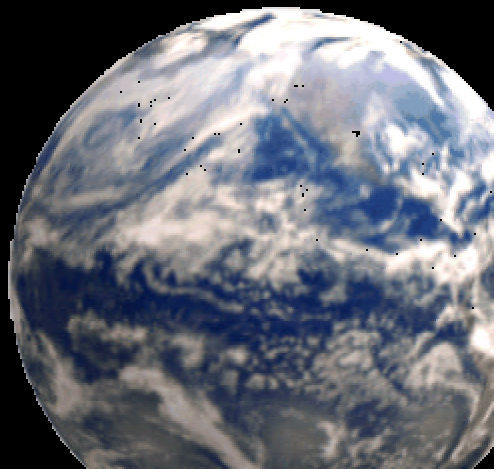
Associate Administrator

NASA Office of Life & Microgravity Sciences & Applications

NASA Vision

NASA is an investment in America's future.

As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.



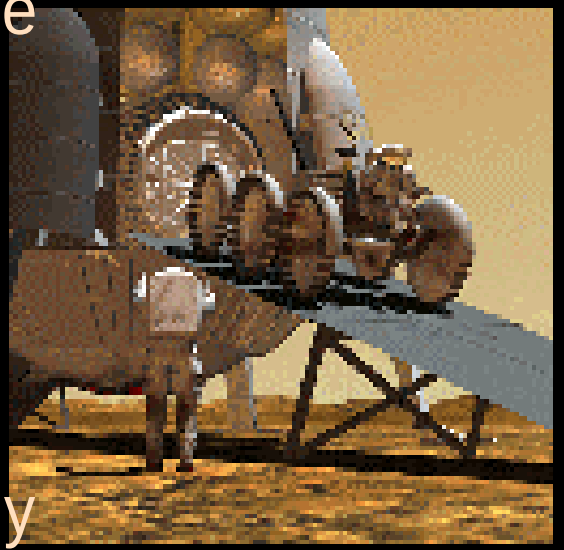
Strategic Framework

NASA's MISSION

…advance…knowledge

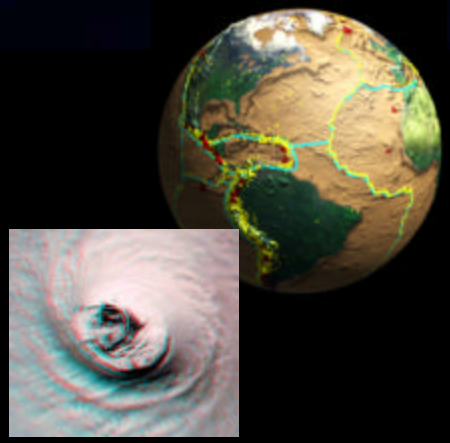
…explore…space

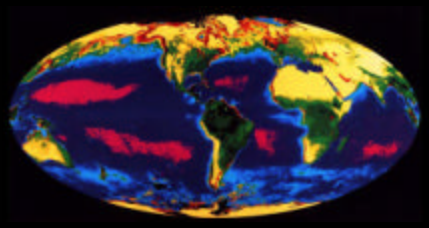
…transfer…technology



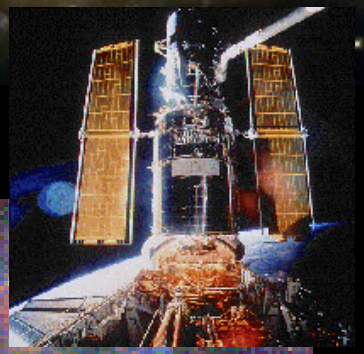
NASA Science

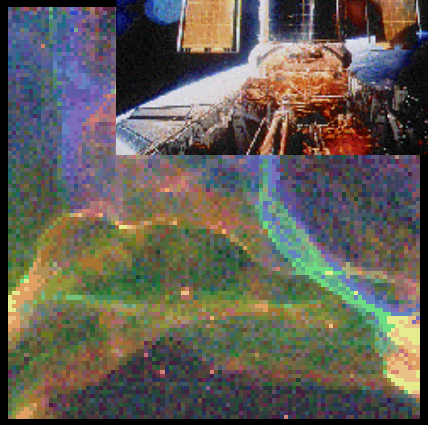
FROM
Space





ABOUT
Space



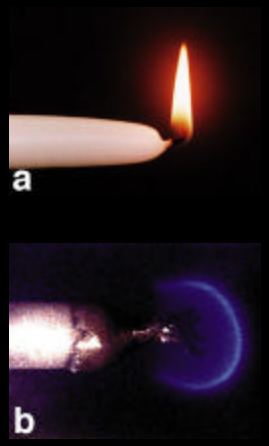


IN
Space

Attributes of Space

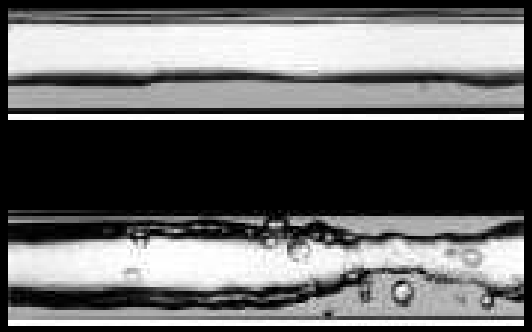
In microgravity, there is no…..

Convection



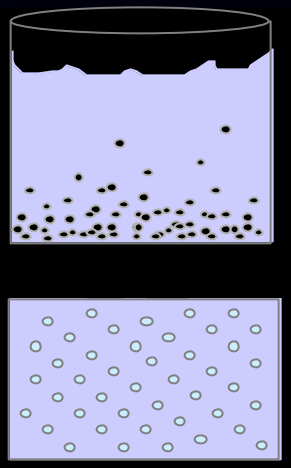
A candle burns on Earth (top) & in microgravity (bottom).

Buoyancy



Fluid flows through a pipe in Earth's gravity (top) and in microgravity (bottom).

Sedimentation



On Earth, particulates settle out of a liquid (top), but in space, particulates are suspended evenly (bottom).

OLMSA's Role

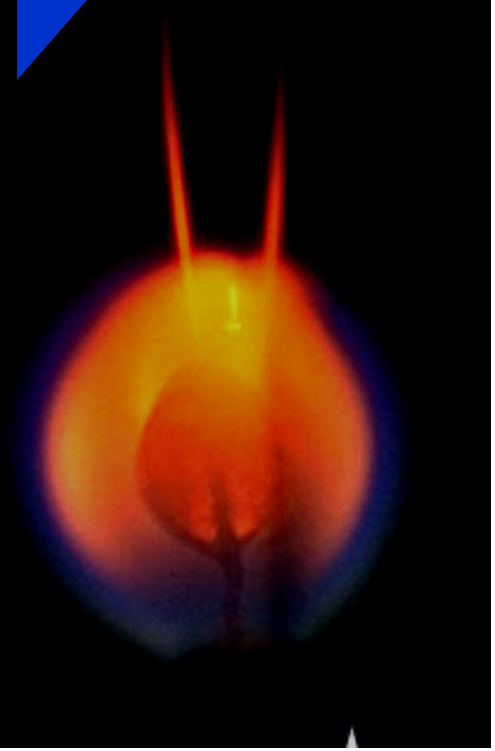
Understanding the role of Gravity

Use the space environment for research

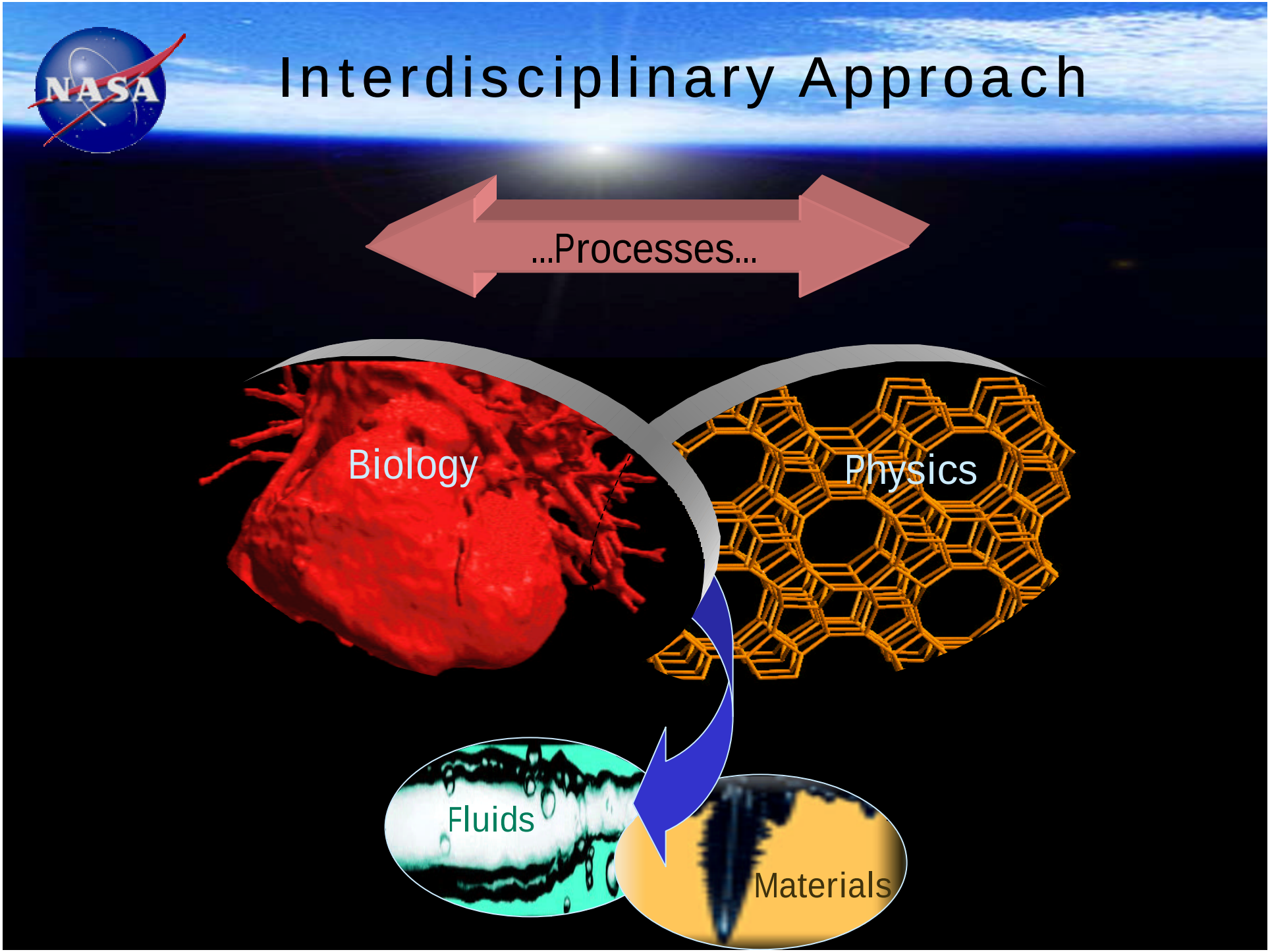
Facilitate the commercial use of space

dose ⟷ response

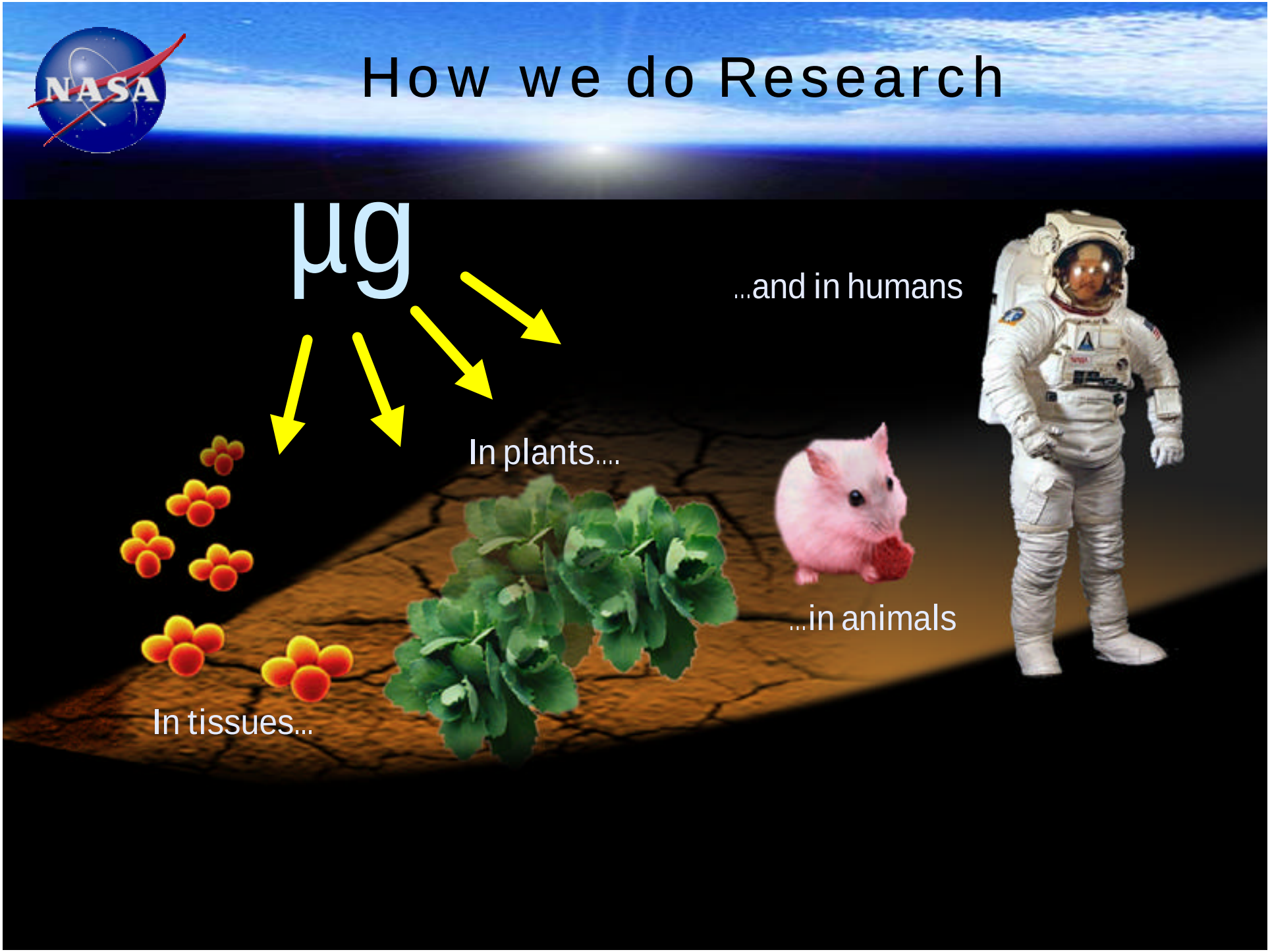
Enable safe human exploration



Interdisciplinary Approach

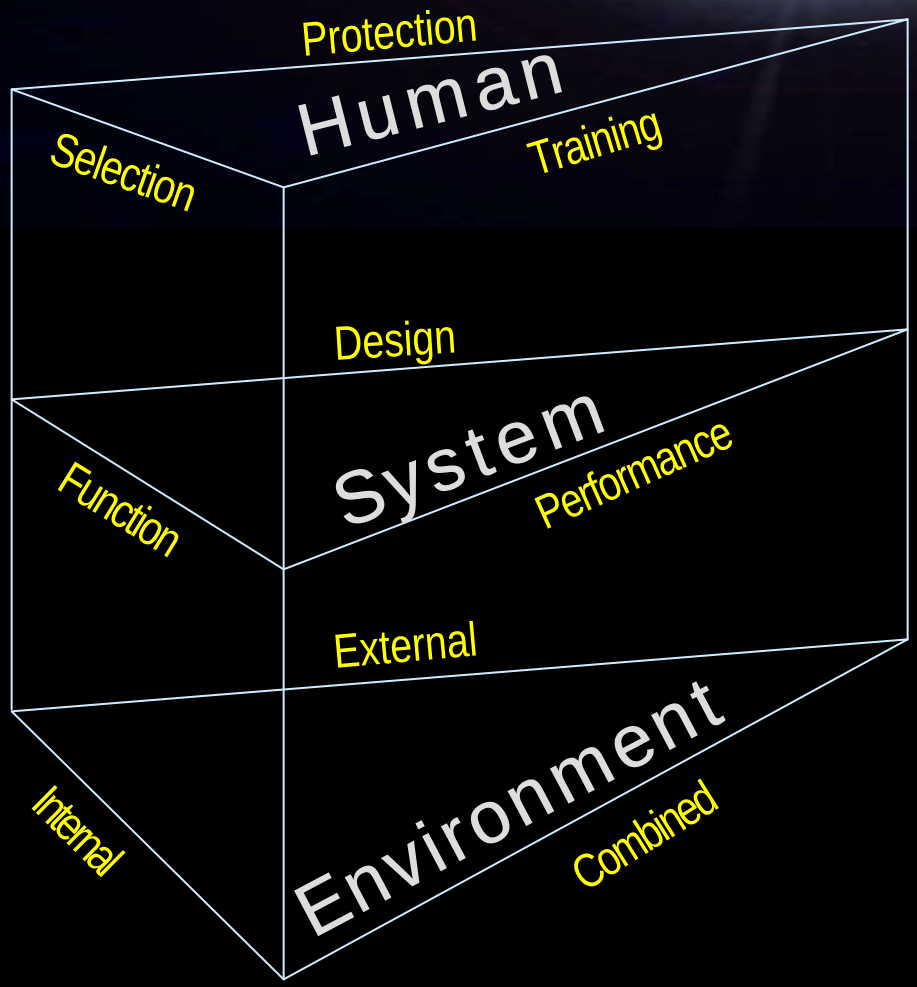


How we do Research



Human Space Mission Architecture

Human
System
Environment



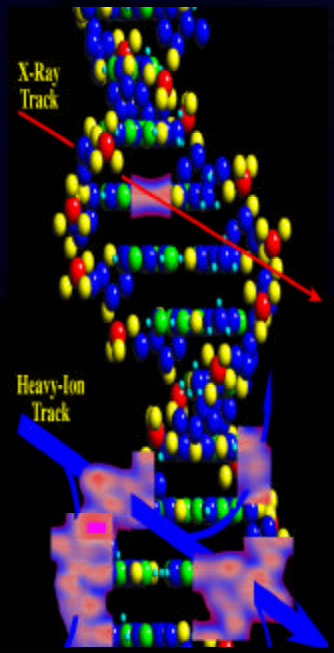
Designers must facilitate Human performance…

…by creating a System that responds effectively…

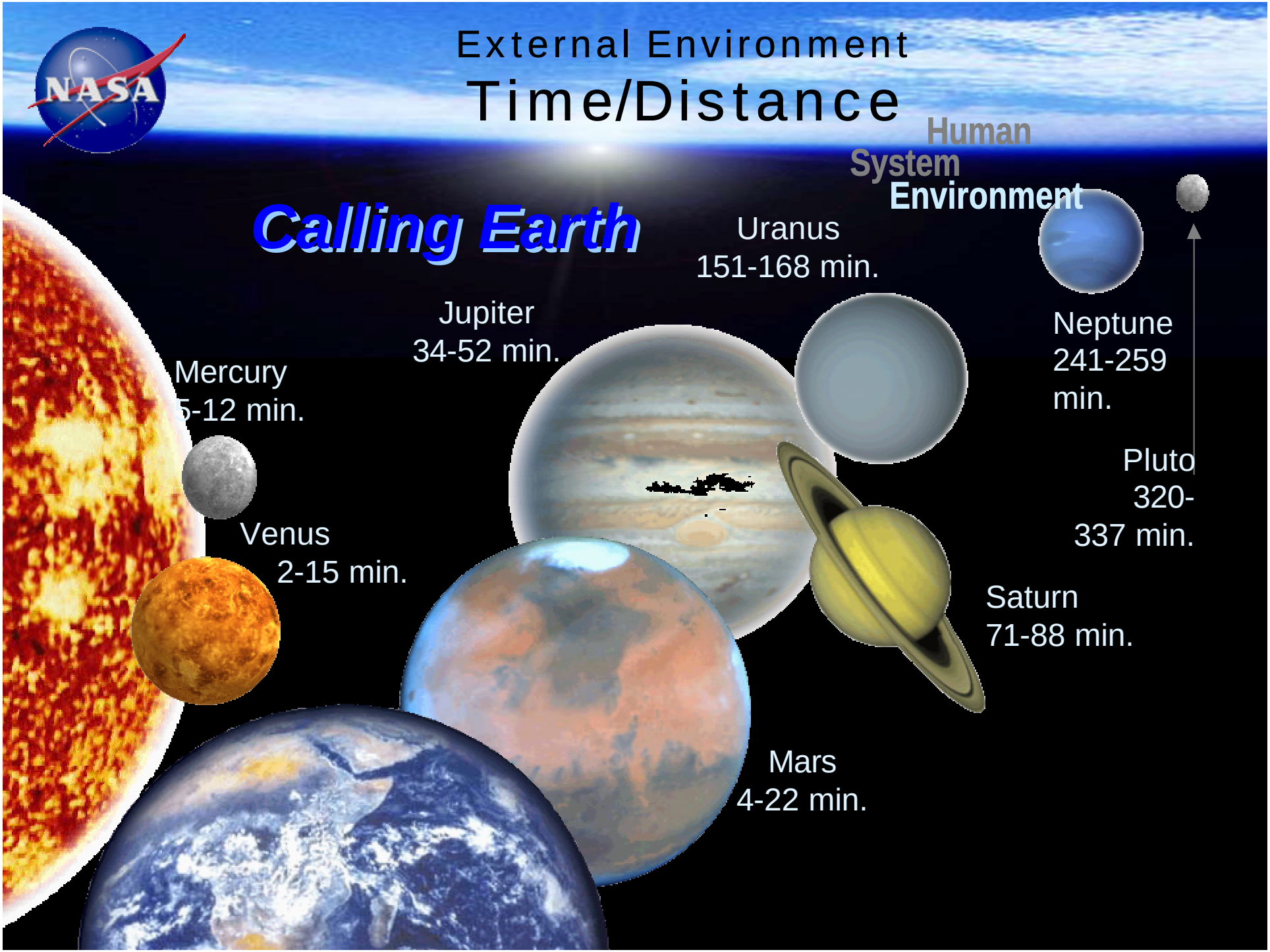
…to the challenges of the space flight Environment.

External Environment

Human System Environment



- Microgravity
- Radiation
  - ✓ *Cosmic (steady)*
  - ✓ *Solar (variable flux)*
- Temperature extremes
- Intolerable pressures
  - ✓ *Vacuum*
  - ✓ *High pressures one day?*
- Biological threat?
- Time/distance


External Environment
Time/Distance
Human System Environment
Calling Earth
Uranus
151-168 min.
Jupiter
34-52 min.
Neptune
241-259
min.
Mercury
5-12 min.
Pluto
320-
337 min.
Venus
2-15 min.
Saturn
71-88 min.
Mars
4-22 min.

Internal Environment

Human System Environment

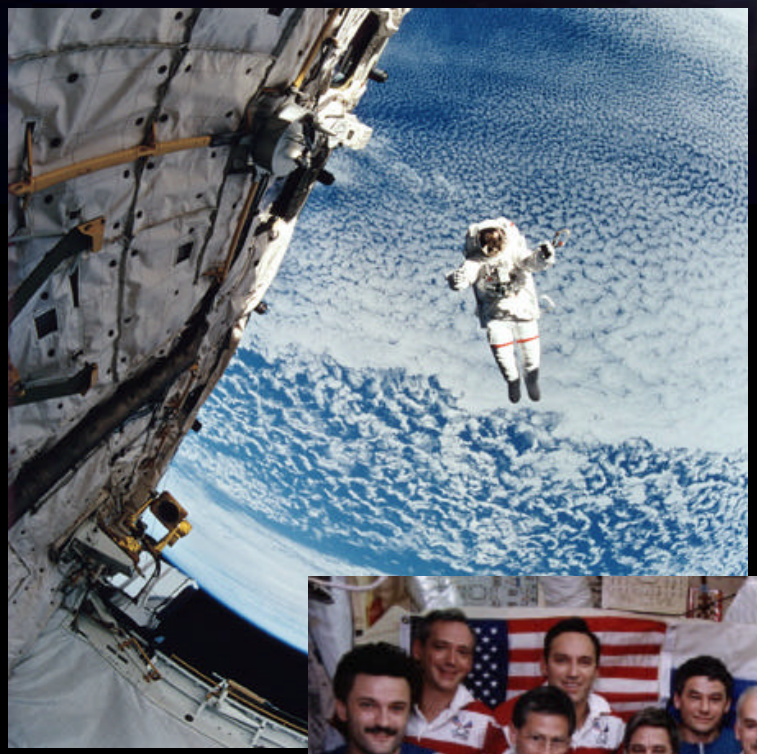
Habitat configuration

- Atmospheric composition/ pressure
- Toxicology
- Ergonomics
- Recreation facilities
- Protection

System configuration is intimately tied to internal environmental conditions.

Internal Psychosocial Elements

Human
System
Environment

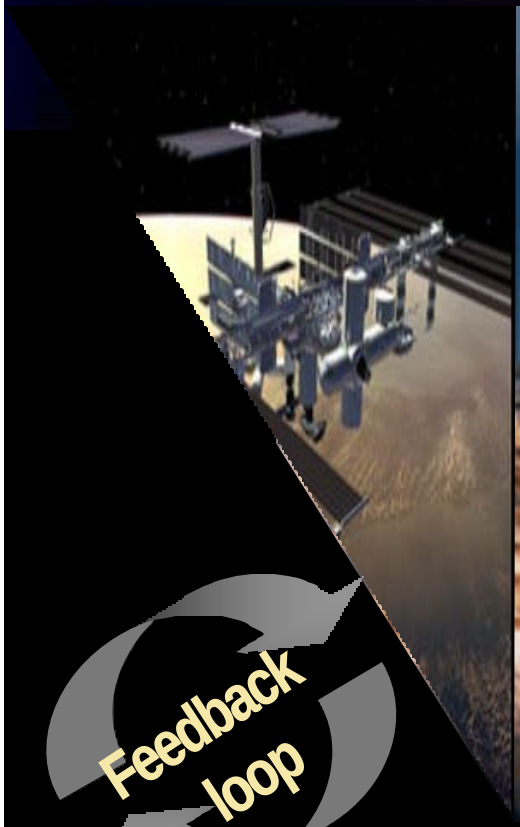


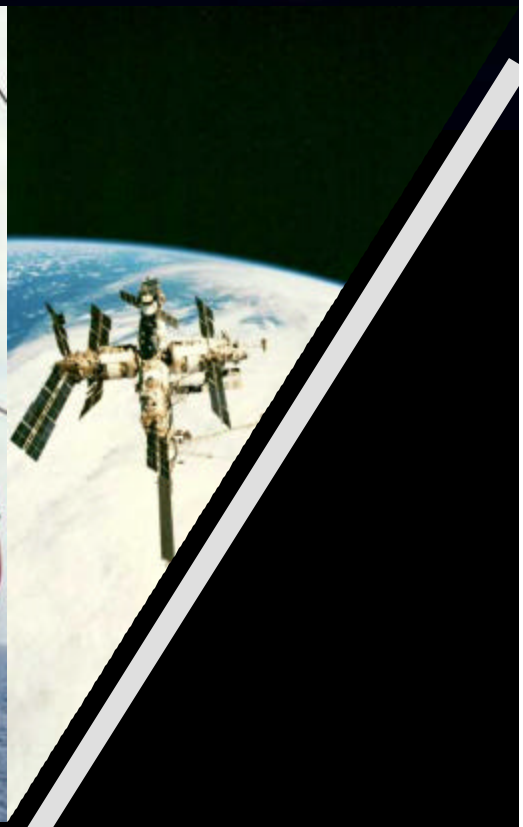
- Isolation
- Confinement
- Multicultural factors
- Societal issues

System

Human
System
Environment

Function → **Performance**





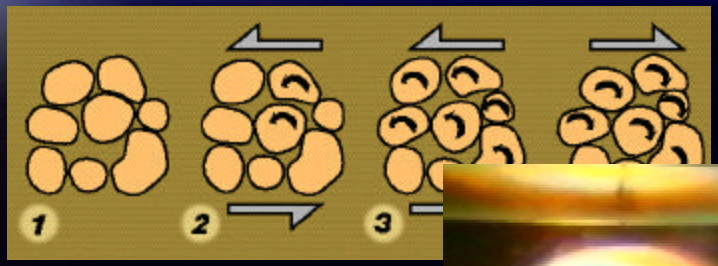
Feedback loop

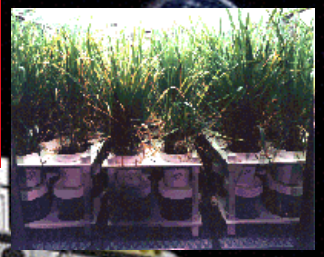
Design

Microgravity Sciences and Exploration System Design

- Spacecraft protection
  - ✓ *Materials science (shielding)*
  - ✓ *Biotechnology (organic materials)*
- Life support systems
  - ✓ *Fluid physics (air and water flow)*
  - ✓ *Combustion science (fire suppression)*
  - ✓ *Fundamental biology (nutrient production)*
  - ✓ *Biotechnology (biosensors)*
- In situ resource utilization
  - ✓ *Granular materials (soil behavior)*
  - ✓ *Combustion science (energy production)*
  - ✓ *Fundamental physics (energy control)*

…and more...





Crew Selection

Human
System
Environment

Crew selection takes into consideration

Medical standards

Skills composition

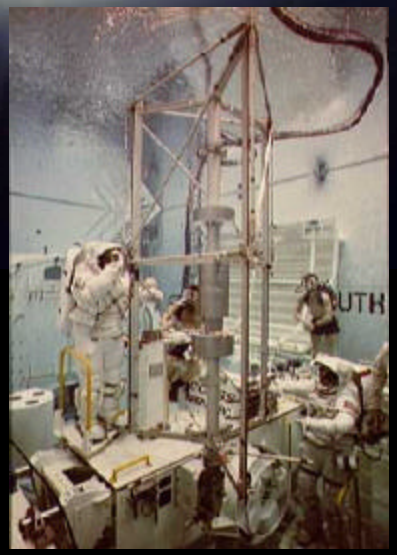
Psychological suitability

Crew compatibility

Crew Training

Human System Environment

- Survival
- Mission-specific
- Experiments
- Medical skills



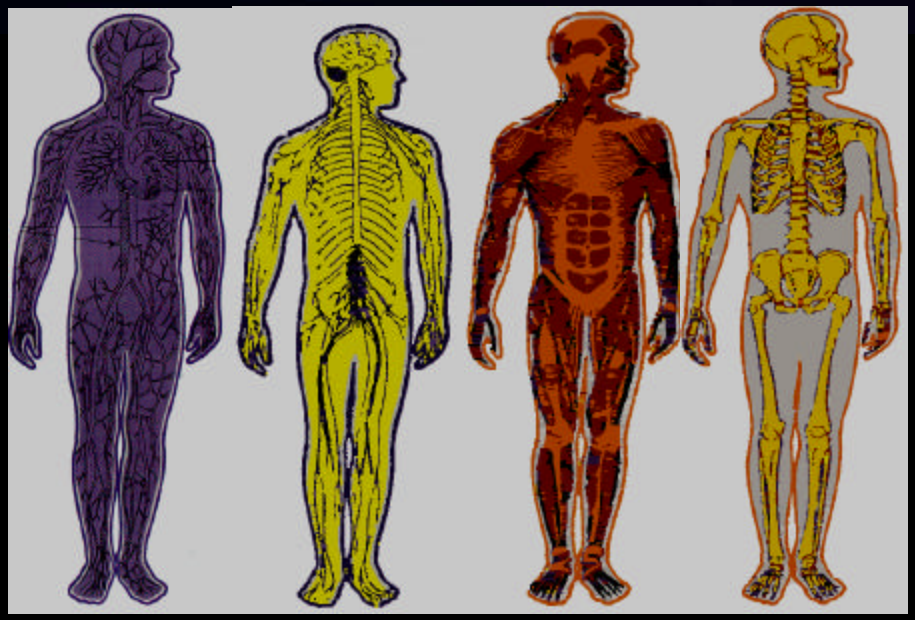
Protection

- Preventive care
- Interventions
  - ✓ *Countermeasures*
  - ✓ *Medical care*
- Life support design choices (system)

Countermeasures

Mechanism

Plasticity	Receptor adjustment	Long chain myosin	Bone formation
Ataxia	Fluid loss (2 L), BP control	Muscle fiber shift & strength decrease	Reduction 1%/ month



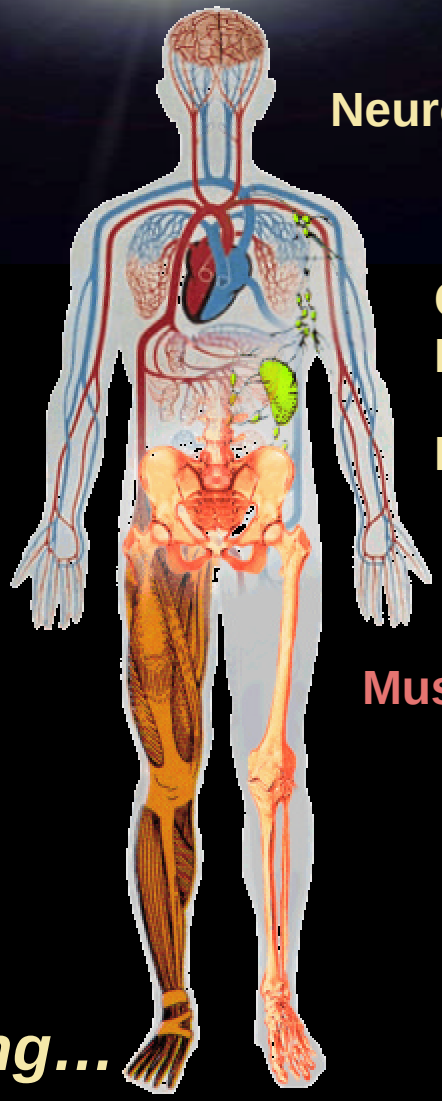
Manifestation

- Traditional
  - ✓ *Exercise*
  - ✓ *Nutrition*
  - ✓ *Fluids*
  - ✓ *Pharmacological supplements*
- Non-traditional
  - ✓ *Artificial gravity*
  - ✓ *Intervention at genetic/molecular level*

Human Adaptation to Space Flight

Adaptive

Pathological



Neurosensory & Neuromotor

Cardiovascular/ Pulmonary

Endocrine

Musculoskeletal

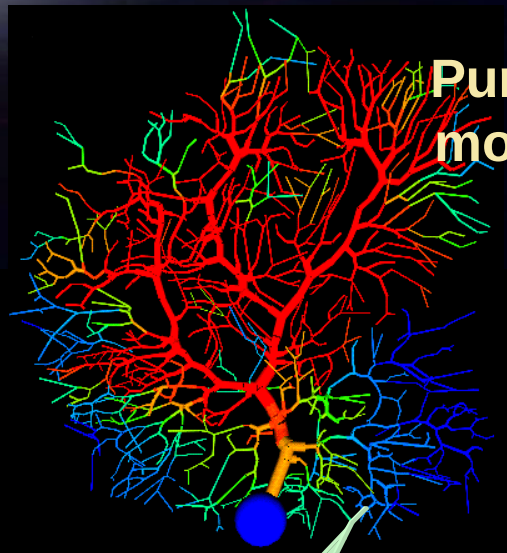
Radiation

Confinement

parallels with aging…

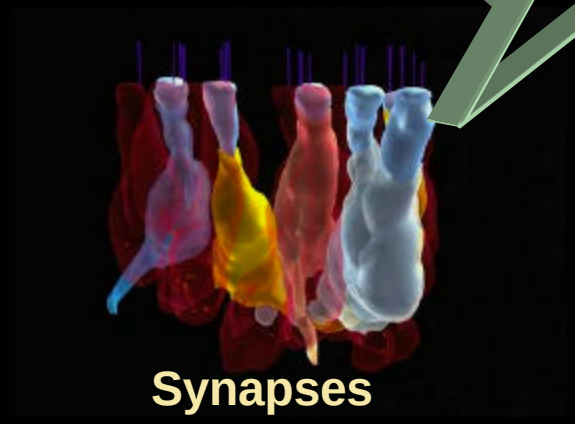
Plasticity

Rapid changes in function and structure to high or low acceleration forces



Purkinje cell morphology

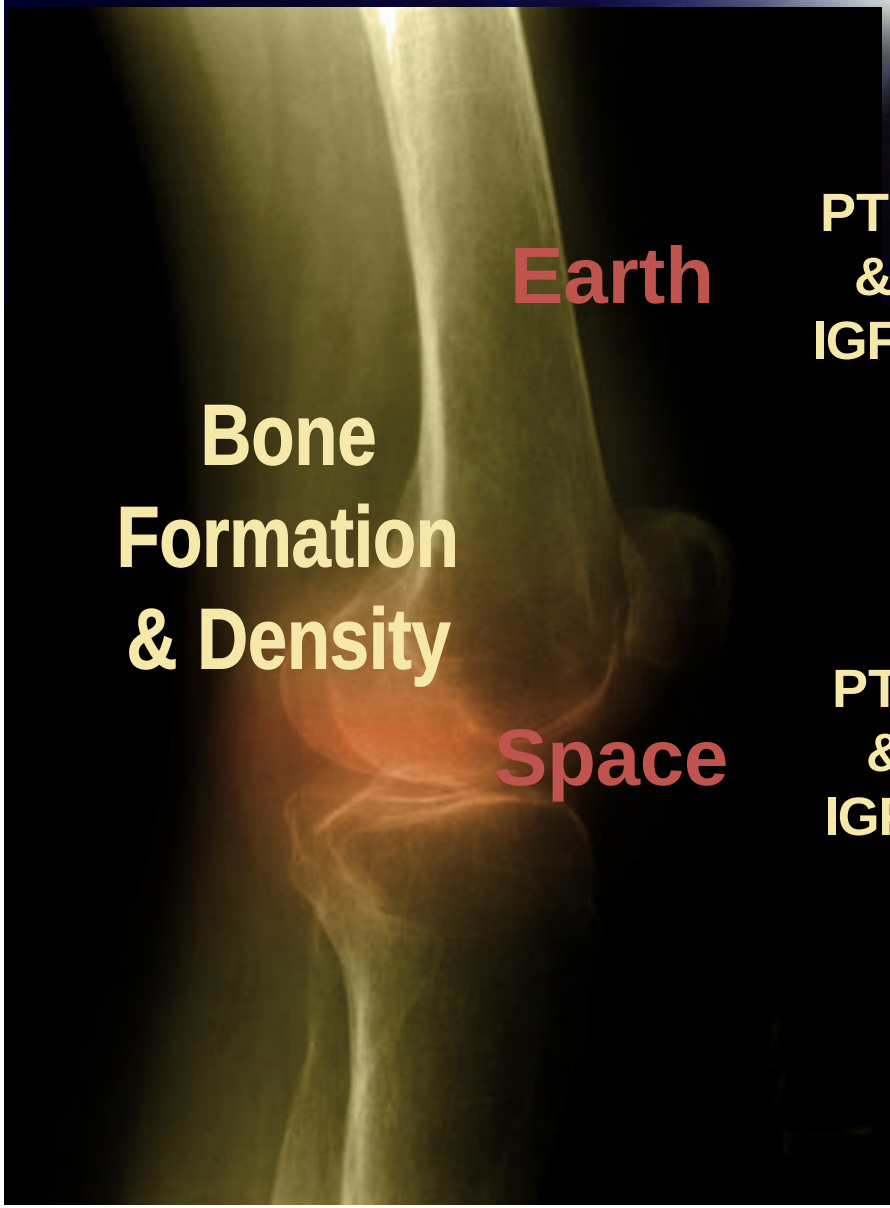
Type of Response



Synapses

Ataxia
SMS
Occular

Bone Response



Bone Formation & Density

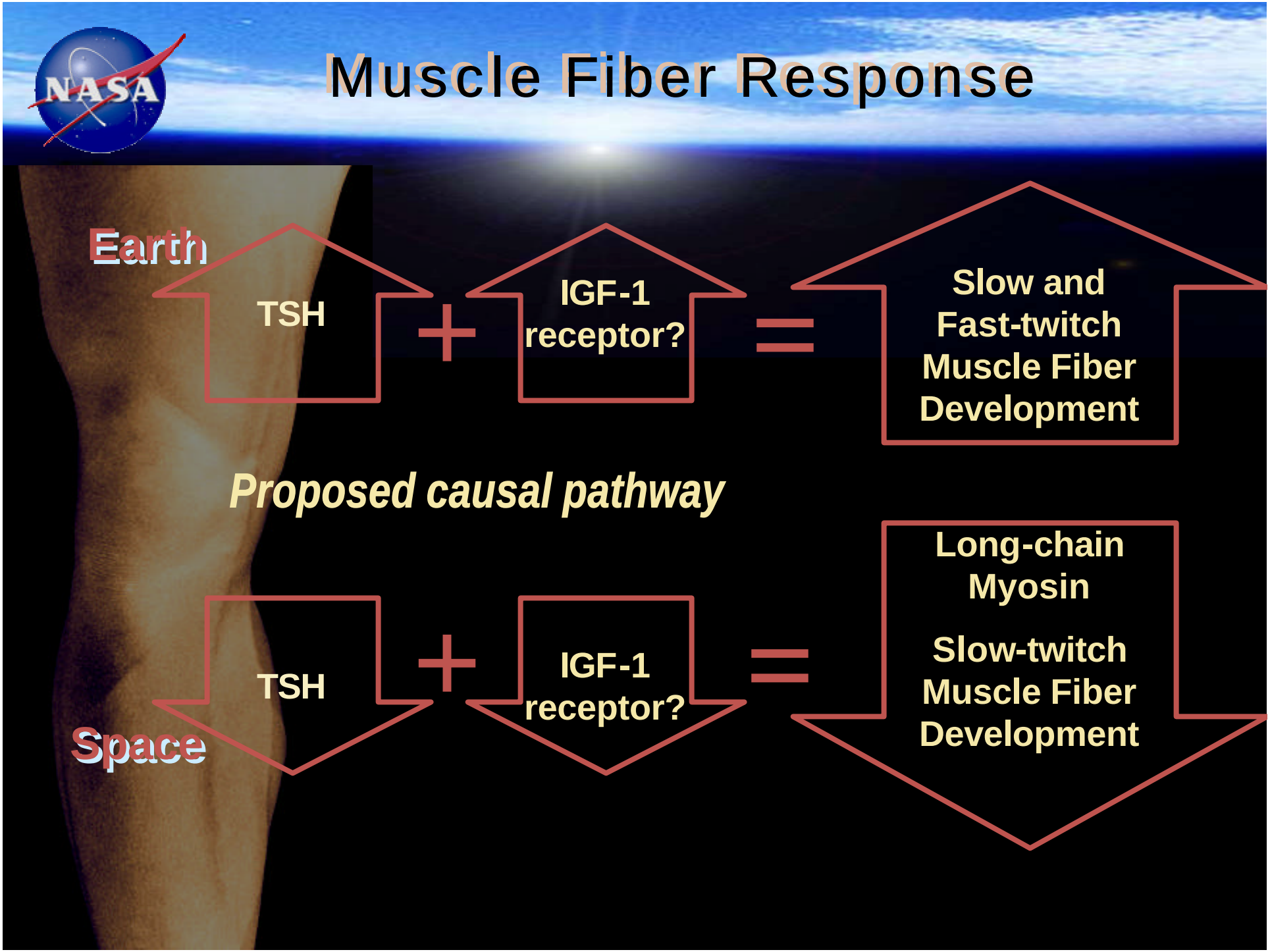
Earth

PTH & IGF-I ↑ = **Osteoprogenitor Number & Bone Mineralization**

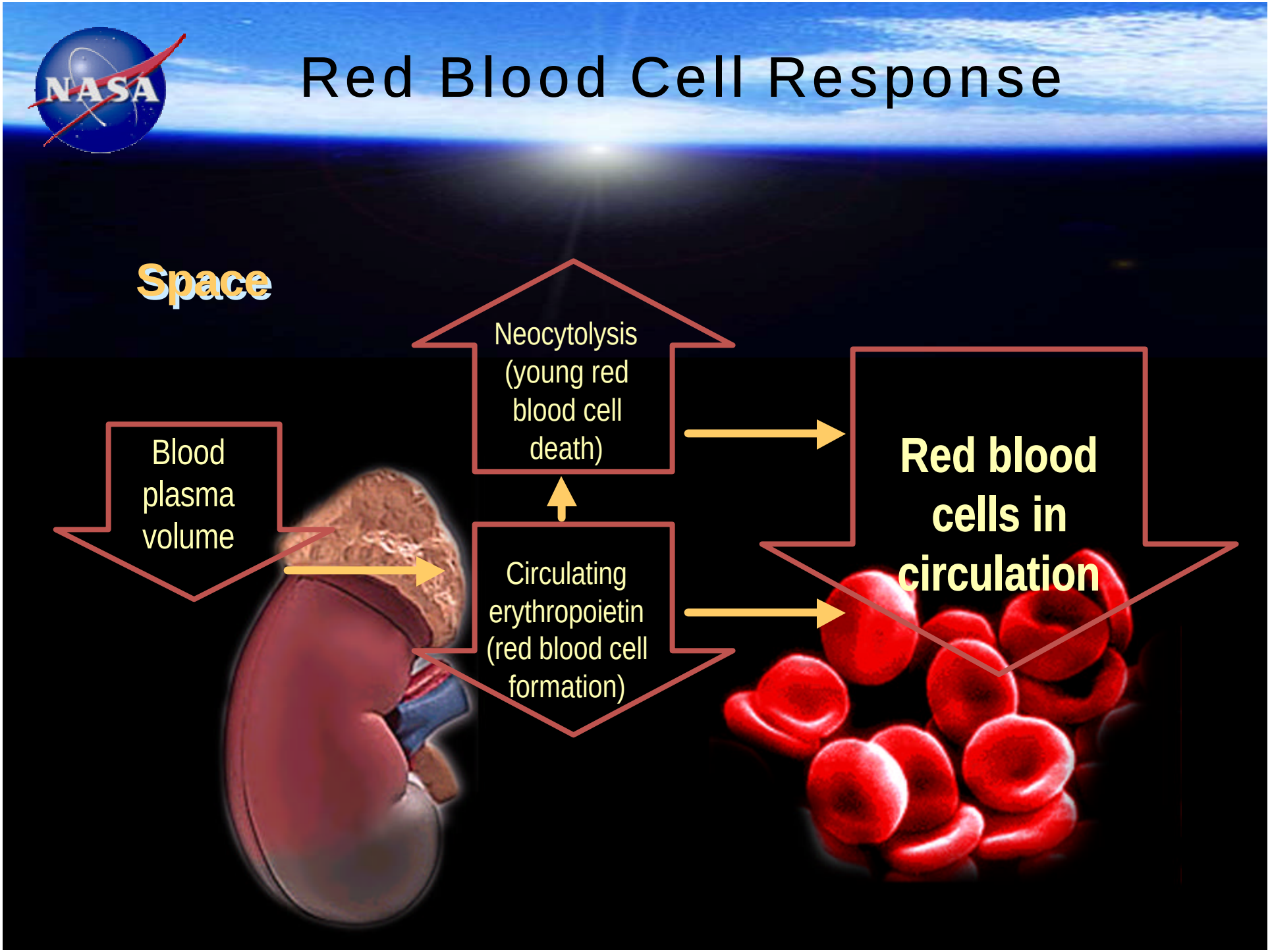
Space

PTH & IGF-I ↓ = **Osteoprogenitor Number & Bone Mineralization**

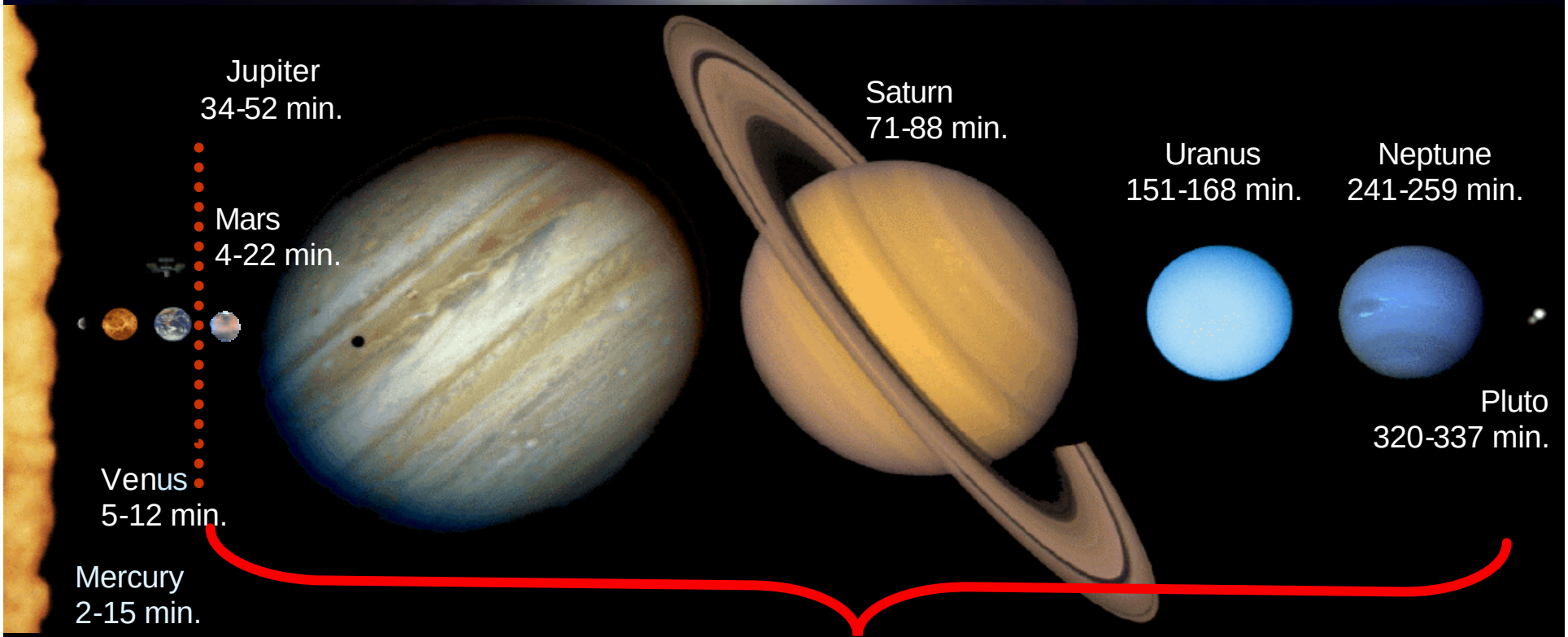
Muscle Fiber Response



Red Blood Cell Response



Communications Challenge: Time and Space

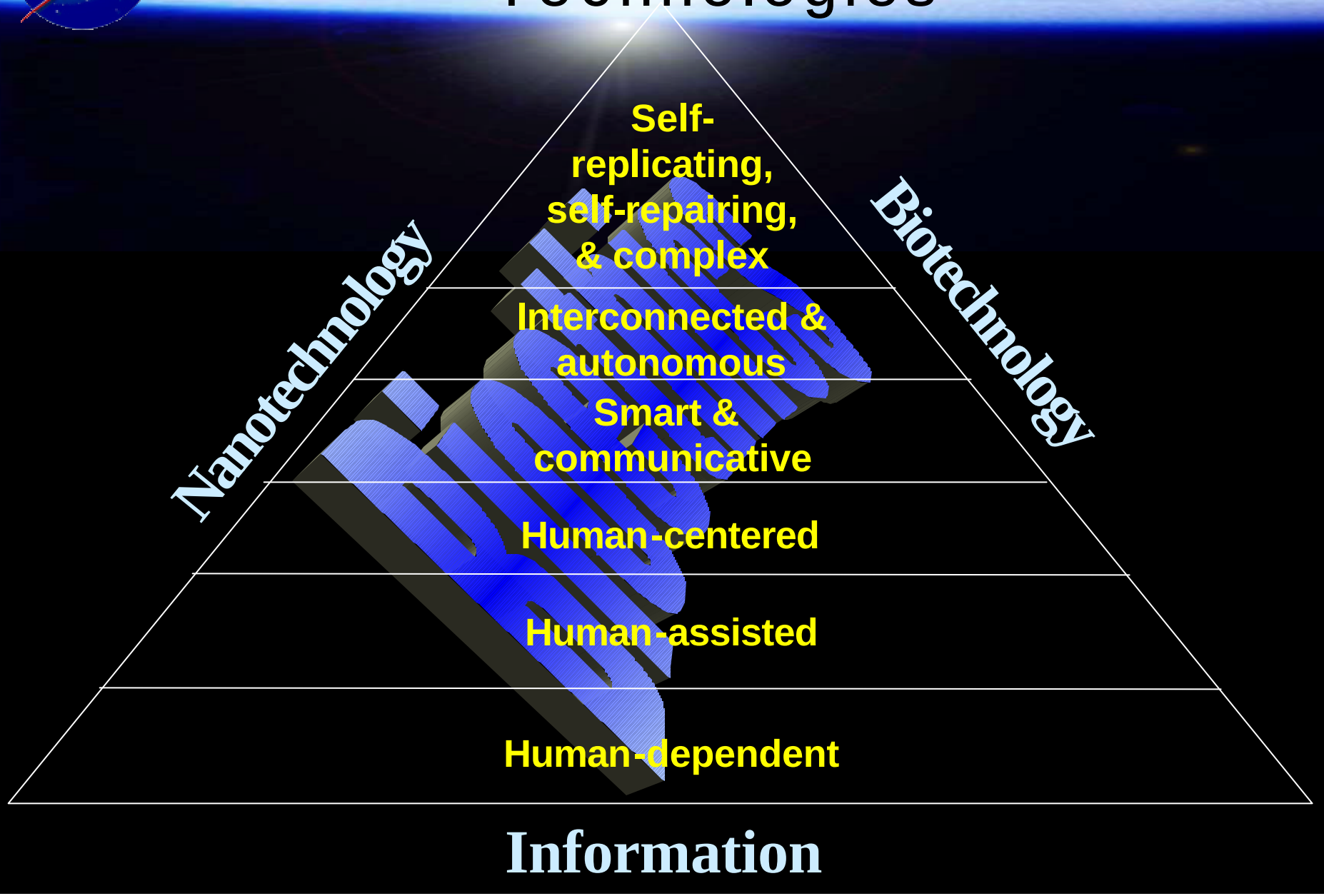


Store-and-forward
Autonomy

Real-time communications

+ Air/ground & EVA/IVA

Hierarchy of Medical Technologies



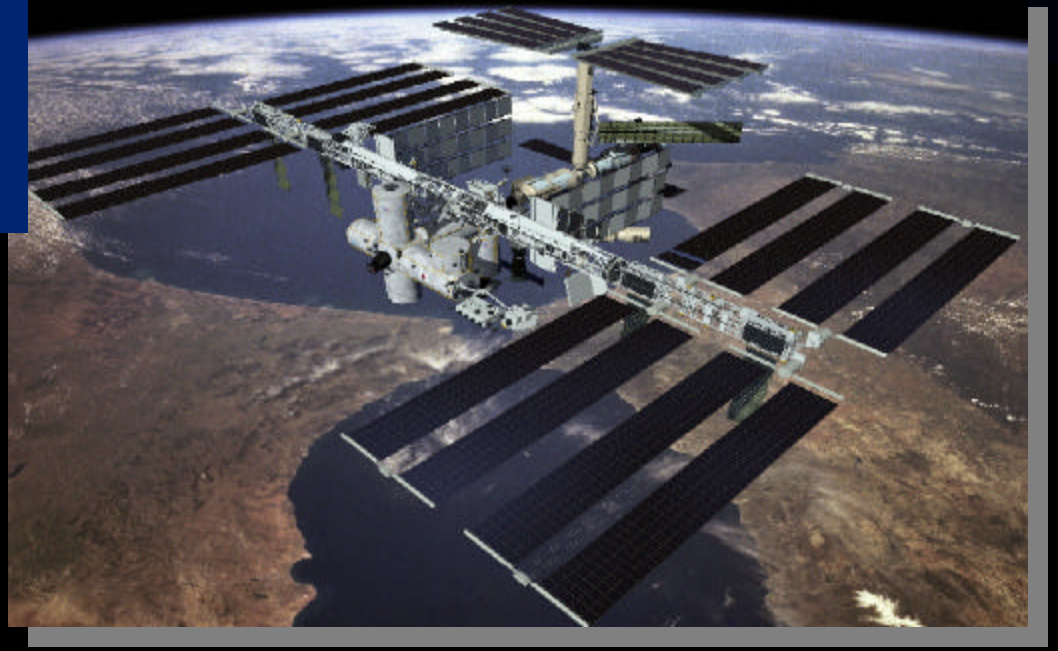
Bioastronautics

- Habitation/ Environmental Health
- Human Adaptation/ Countermeasures
- Health Care Systems

People living and working in space

Station as a Testbed

Station is an integrated test platform for exploration science, technologies, and operations.



History

Exploration

Human Survival

Response Characterization

Molecular & Cellular Bases of µg responses

Apollo
Gemini
Mercury

Skylab

Shuttle/Spacelab

Shuttle/*Mir*

ISS

1960 1970 1980 1990 2000

Human Adaptation/Endurance

Fundamental & Focused

Observational

Basic & Commercial

.....*Research capacity*

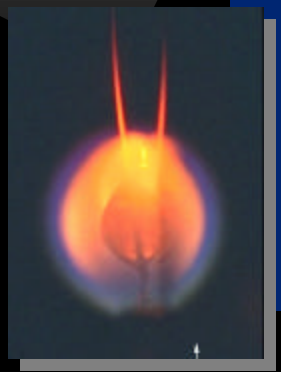
Back-up

System Function

Human
System
Environment

Mission objectives define system function: ***transport, protect, and provide for the crew.***

- Life support
- Fire prevention & suppression
- Environmental control systems
- Shielding materials
- Support systems



Underlying research

Fluid physics
Materials science
Combustion science
Fundamental biology
Fundamental physics

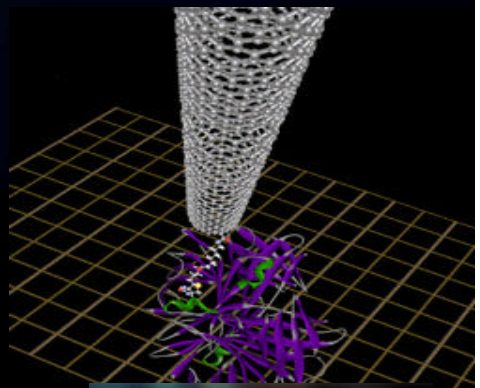
System Design

Human
System
Environment

System design accommodates constraints on available power; mass; and crew size, expertise, and availability. Technological and economic trade-offs determine ultimate design.

Human factors

- Accessibility
- Ease-of-use



Biologically-inspired technologies

- Miniaturization
- Autonomy
- Redundancy

System Performance

Human
System
Environment

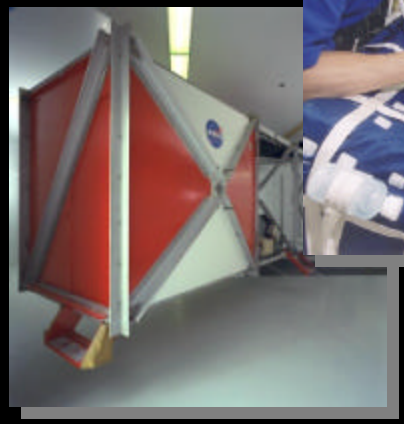
- System performance parameters/limits
- Emergency procedures

Performance parameters are chosen to accommodate crew needs and available technology .

- Standard operating procedures
  - ✓ *Vehicle/habitat operations*
  - ✓ *Maintenance procedures*
  - ✓ *Medical care standards*
  - ✓ *Work/rest cycles*

Crew Training

Human System Environment



Virtual reality

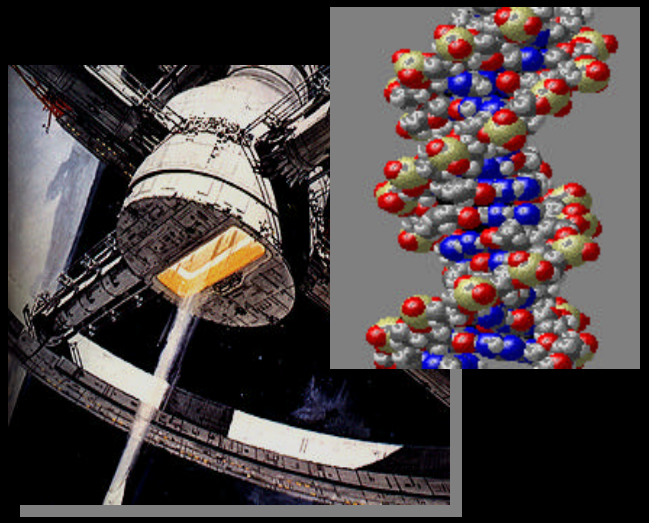
- Survival
- Mission-specific
  - ✓ *Operations*
  - ✓ *Research procedures*
- Medical care
  - ✓ *Routine assessments*
  - ✓ *Emergency interventions*

Pre-mission training will focus on general skills development, while real-time training throughout the mission will instruct the crew on specific tasks.

Crew Protection

Human System Environment

Crew well-being is protected through a series of physical and psychological countermeasures.



- Countermeasures
  - ✓ *Traditional*
    - exercise
    - nutrition
    - fluids
    - pharmacological supplements
  - ✓ *Non-traditional*
    - artificial gravity
    - intervention at genetic/molecular level
- Psychological support

Health Care Needs Beyond LEO

The remoteness of exploration-class missions generates a unique set of requirement for health care systems

- Compact
- Lightweight
- Portable
- Low maintenance
- Easy-to-use
- Autonomous
- Minimally invasive

Medical informatics is the cross-cutting technology

- Interface capability
- Presentational/display versatility
- Flexibility
- Computational power

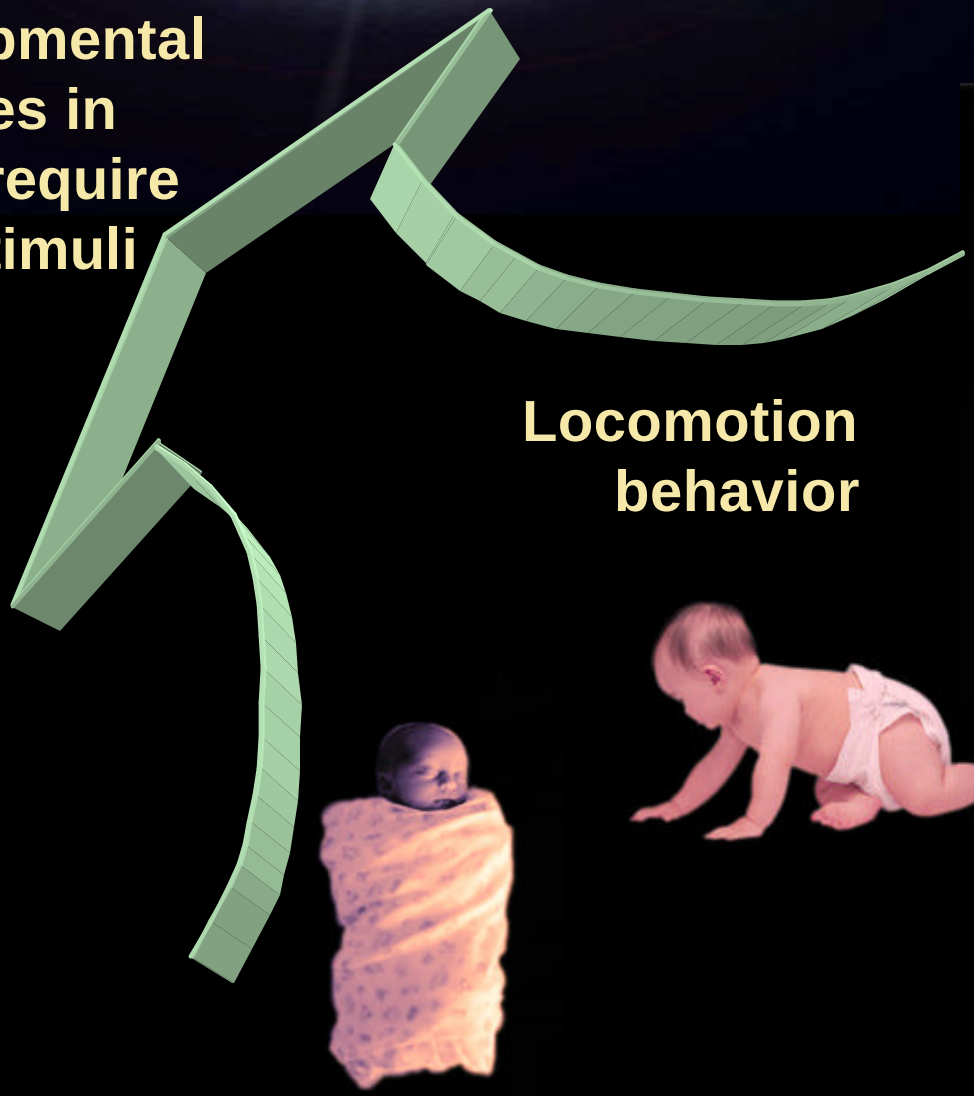
Preventive Care Emphasis

NASA has traditionally focused on preventive care to keep flight crews healthy

- Astronaut selection standards
  - ✓ *Physical health*
  - ✓ *Psychological considerations*
- Preflight health certifications
  - ✓ *Screenings*
  - ✓ *Spaceflight health requirements*
- Protection of human research subjects
  - ✓ *Overseen by JSC Institutional Review Board*
  - ✓ *Rigorous informed consent*
  - ✓ *Suspension of testing upon request, illness, or injury*

Development

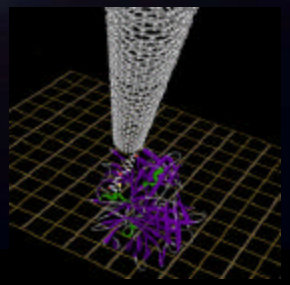
Key developmental processes in mammals require gravity stimuli



Locomotion behavior

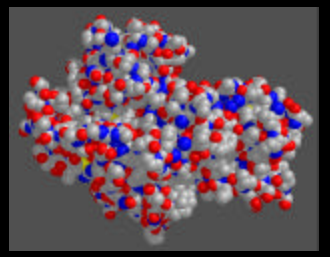
Biology-inspired Technology Research

- ✓ *Human-centered Systems*
- ✓ *Robotics*
- ✓ *Smart Materials & Structures*
- ✓ *Virtual Biology Inspired Technology Center providing intellectual leadership*
- ✓ *Cooperative Agreement Notice will be released in March 2000*

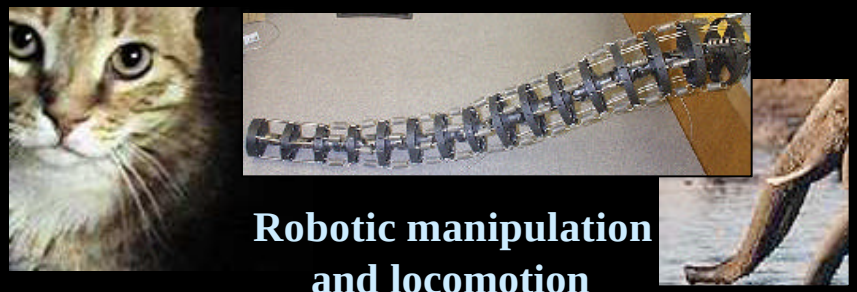


New class of unnatural folding oligomers

Electronic Nose and Tongue for environmental monitoring



Motor proteins as shuttles

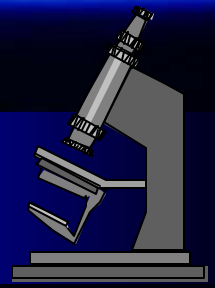


Robotic manipulation and locomotion

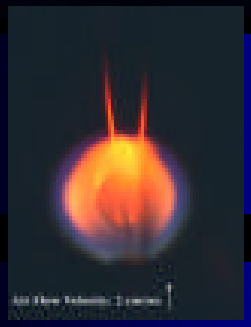
Bioastronautics Initiative

Bioastronautics integrates research, technology development, and mission planning to enhance the safety and productivity of flight crews, with benefits for the health and well-being of people on Earth

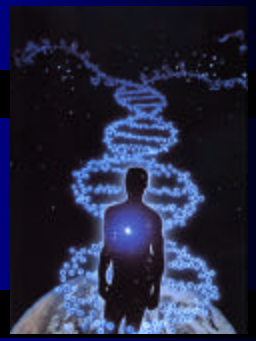
OLMSA Outcomes



Expanding Knowledge



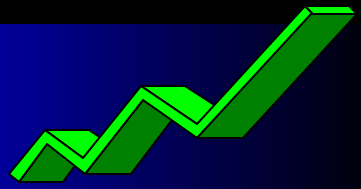
Improving Industrial Processes



Looking After Health on Earth & in Space

Enabling Exploration

Researching Tomorrow's Products



Current OLMSA Research Platforms

Ground/Atmospheric

- Aircraft
- Sub-orbital rockets
- Drop towers/tubes
- Centrifuges
- Particle accelerators (radiation research)
- Closed-environment test-beds

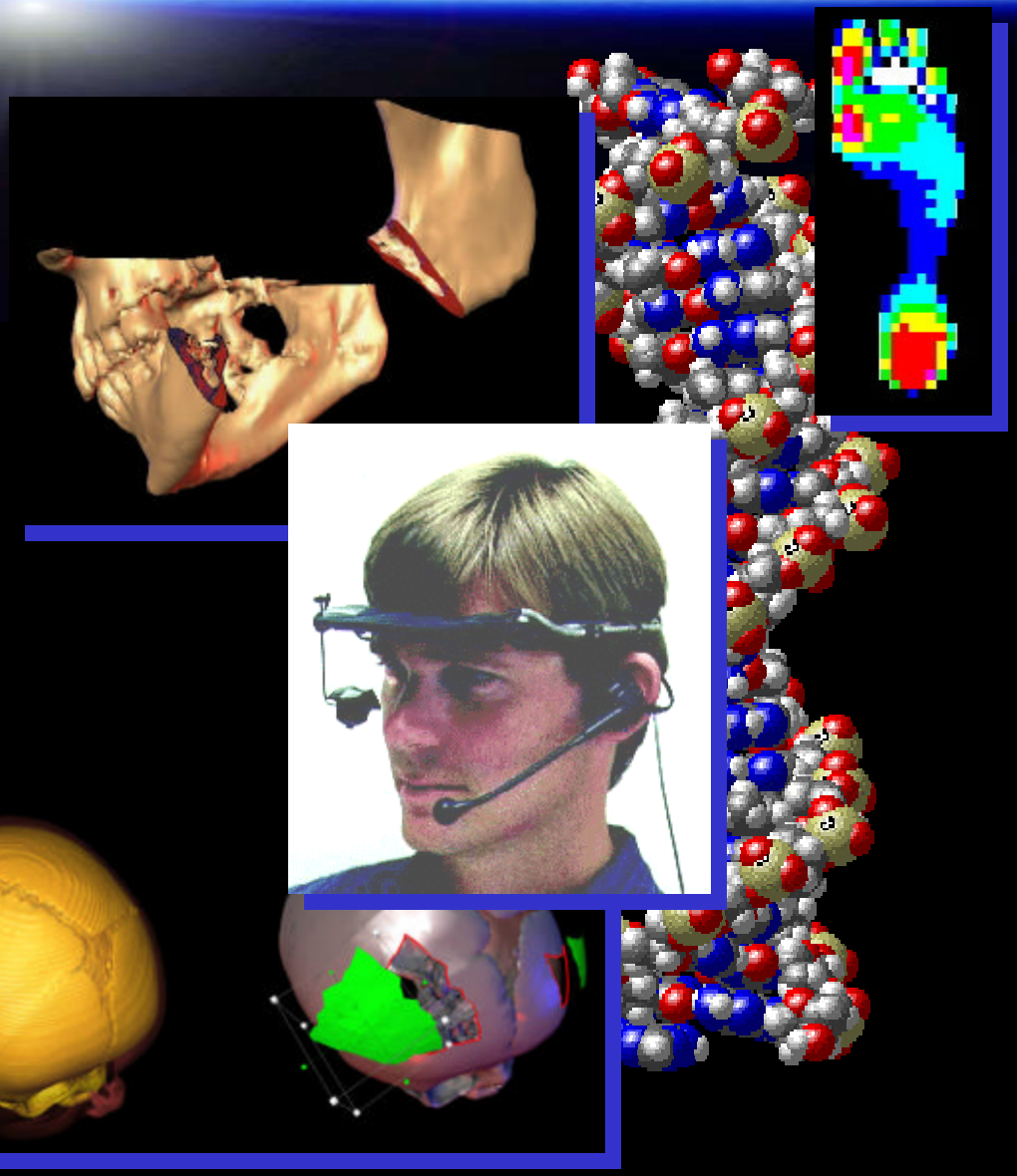
Space Flight

- Shuttle
- International Space Station

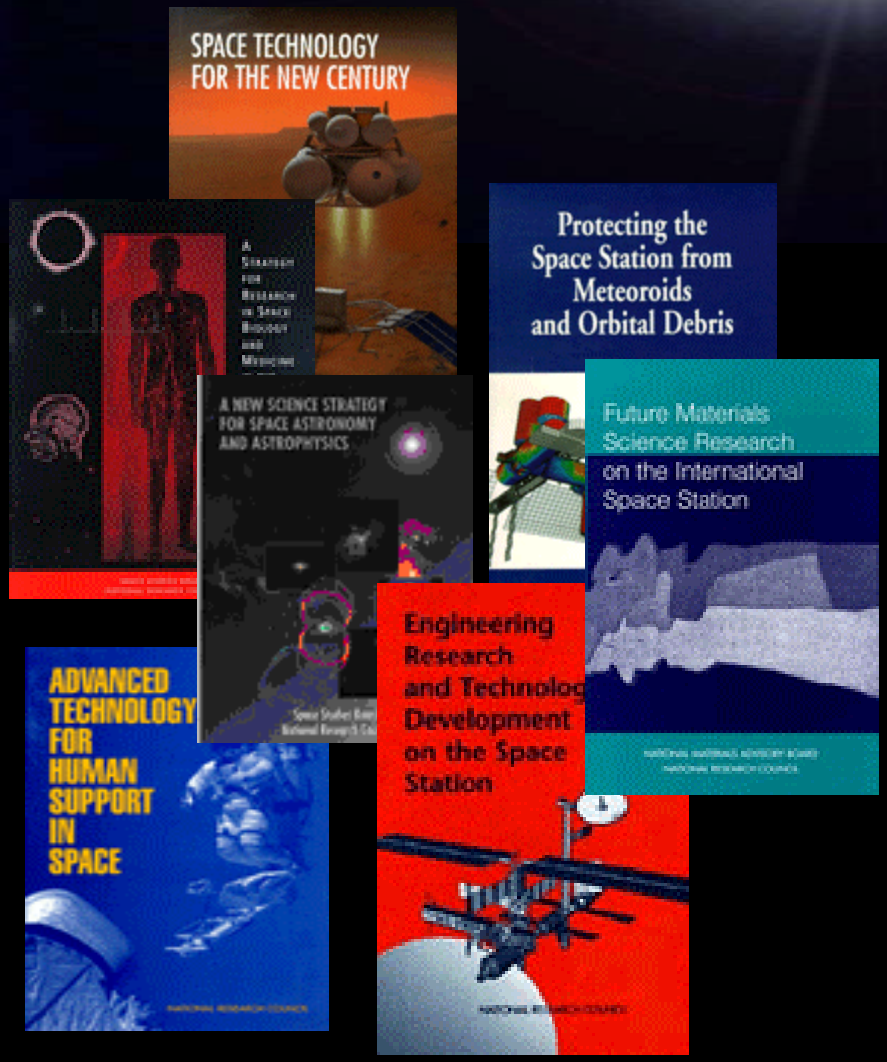
Research proposals are evaluated by peer review committees and are competitively selected by science quality and relevance

Cross-cutting Technology Needs

- Portability
- Miniaturization
- Virtual reality
- Artificial intelligence
- Biologically-inspired technologies



National Guidance



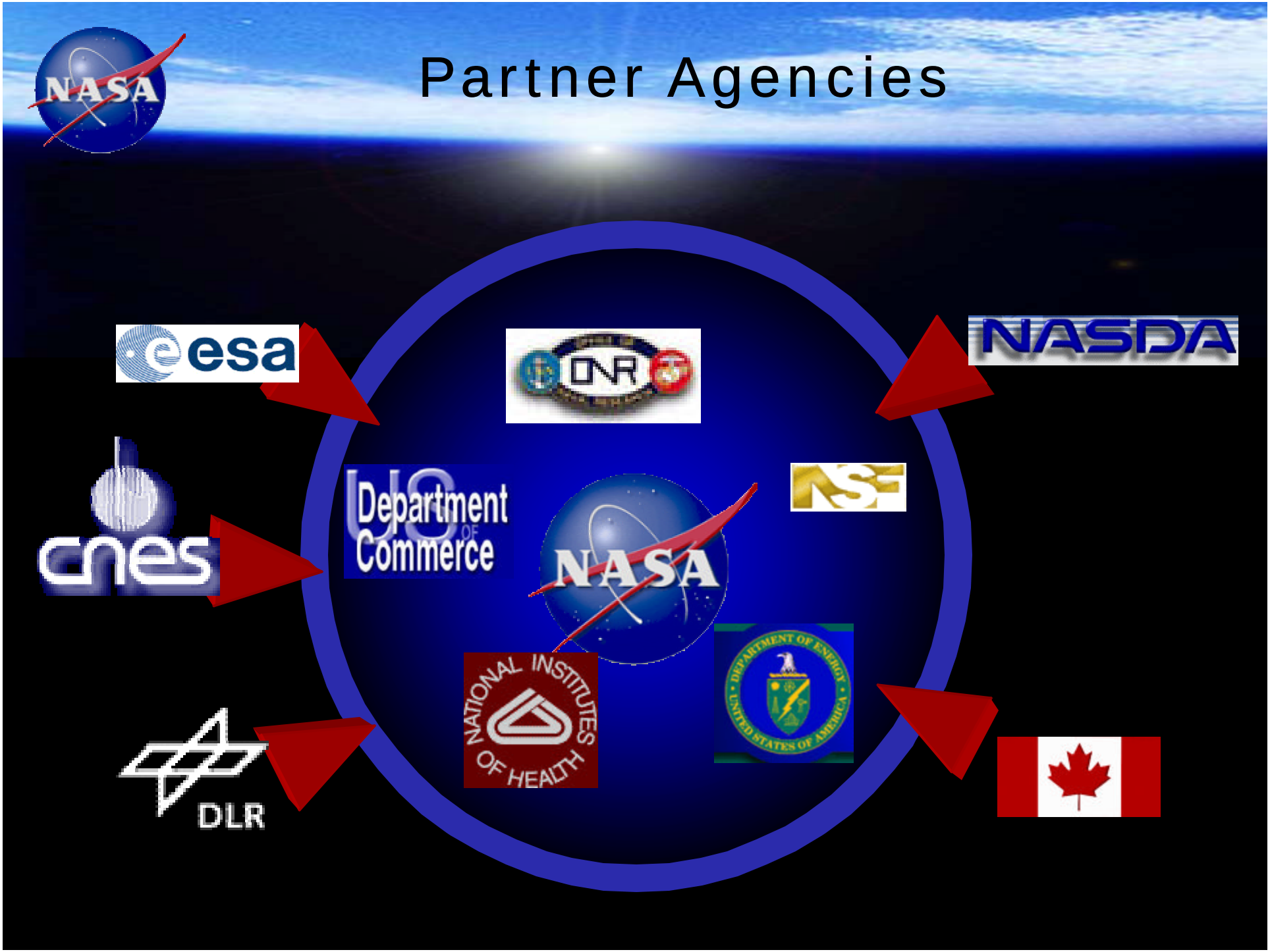
ISS Utilization plans are guided by national advisory committees…

- *Space Studies Board (NRC)*
- *Board on Health Science Policies (IOM)*
- *Board on Physics & Astronomy (NRC)*
- *Aeronautics & Space Engineering Board (NRC)*

NASA's Research Directions

NASA has developed research directions for the International Space Station in accordance with internal and external advisory bodies and utilizing Phase I Shuttle-Mir experience.

Partner Agencies



International Collaboration

OLMSA collaborates with international partners in the planning and solicitation of research

International Space Life Sciences Working Group

* 

4 life sciences research proposals from France selected for ISS

International Microgravity Strategic Planning Group

4 microgravity investigations with French participation selected for ISS

*Membership under consideration